NUREG-1724

Draft Standard Review Plan

for the Review of DOE Plans for Achieving Regulatory Compliance at Sites with Contaminated Ground Water under Title I of the Uranium Mill Tailings Radiation Control Act

Draft Report for Comment

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555-0001

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COMMENTS ON DRAFT REPORT

Any interested party may submit comments on this report for consideration by the Nuclear Regulatory Commission. Please specify the report number (draft NUREG-1724), in your comments, and send them by the due date published in the *Federal Register* notice to:

Chief, Rules and Directives Branch
Division of Administrative Services
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ABSTRACT

The Department of Energy postponed implementation of ground-water corrective action plans at most Title I sites until completion of surface remediation, because Environmental Protection Agency ground-water standards were not finalized until 1995. Consistent with this approach, 10 CFR 40.27, allows for licensing of disposal sites that require ground-water restoration in two steps. The first step, surface restoration, is conducted by the DOE under the Uranium Mill Tailings Remedial Action Surface Project. After completion of surface restoration, the site is placed under a general license through Nuclear Regulatory Commission acceptance of a Long-Term Surveillance Plan that may leave ground-water restoration issues open. Ground-water corrective action, the second step, is conducted under the Uranium Mill Tailings Remedial Action Ground-Water Project.

This Standard Review Plan is prepared for the guidance of staff reviewers in the Office of Nuclear Material Safety and Safeguards in performing safety and environmental reviews of corrective action plans and revised long-term surveillance plans of ground-water quality compliance activities for uranium recovery sites covered by Title I of the Uranium Mill Tailings Radiation Control Act . The purpose of this Standard Review Plan is to ensure the quality and uniformity of Nuclear Regulatory Commission staff reviews of site-specific documents describing Department of Energy plans for achieving regulatory compliance at sites with contaminated ground water.

This standard review plan is written to cover a variety of site conditions and plans. Each section provides a description of the areas of review, review procedures, acceptance criteria, an evaluation of findings, and a list of references.

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LIST OF ABBREVIATIONS

ACL	alternate concentration limit
ANOVA	analysis of variance
ASTM	American Society for Testing and Materials
CAP	corrective action program
CFR	*Code of Federal Regulations*
DOE	Department of Energy
EAP	emergency action plan
EPA	Environmental Protection Agency
LTSP	long-term surveillance plan
MCL	maximum concentration limit
NRC	Nuclear Regulatory Commission
POC	point of compliance
POE	point of exposure
SRP	standard review plan
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978 as amended
UR	uranium recovery

INTRODUCTION

Protection of water resources at Title I sites is a process that encompasses two distinct strategies. The first strategy is to contain the spread of contaminants to ground water, surface water, and surrounding lands. The second strategy is to mitigate the threat to public health from contaminants that have already been mobilized—particularly through ground-water pathways. The Nuclear Regulatory Commission (NRC) reviews the cleanup of contaminated ground water by the Department of Energy (DOE) at Title I sites to determine if the cleanup complies with applicable sections of the Environmental Protection Agency's standards in 40 CFR Part 192, titled "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings". The DOE has postponed implementation of ground-water corrective action plans at most Title I sites until completion of surface remediation, because Environmental Protection Agency (EPA) ground-water standards were not finalized until 1995. Consistent with this approach, 10 CFR 40.27, allows for licensing of disposal sites that require ground-water restoration in two steps. The first step, surface restoration, is conducted by the DOE under the Uranium Mill Tailings Remedial Action Surface Project. After completion of surface restoration, the site is placed under a general license through Nuclear Regulatory Commission (NRC) acceptance of a Long-Term Surveillance Plan (LTSP) that may leave ground-water restoration issues open. Ground-water corrective action, the second step, is conducted under the Uranium Mill Tailings Remedial Action (UMTRA)Ground-Water Project. The purpose of this Standard Review Plan (SRP) is to aid NRC staff in reviewing site-specific documents describing DOE plans for achieving regulatory compliance at sites with contaminated ground water.

Restoration of contaminated ground water has been postponed, in most cases, until completion of surface reclamation. With the completion of most surface reclamation, and the 1995 publication of final U.S. Environmental Protection Agency (EPA) ground-water standards (60 FR 2854), the DOE has begun to implement the Uranium Mill Tailings Remedial Action Ground-Water Project. Barring the identification of any new Title I sites, the only remedial action plans yet to be reviewed by the NRC for Title I sites should deal solely with implementation of the UMTRA Ground-Water Project. Reviewers of Uranium Mill Tailings Remedial Action Ground-Water Project Remedial Action Plans (sometimes called Ground-Water Compliance Action Plans)shall verify that all of the areas of review outlined in this chapter have been addressed, either through an earlier UMTRA Surface Project Remedial Action Plans (RAPs), or in the Ground-Water Project RAP under review. Reviewers shall also be familiar with the long term surveillance plan (if one exists) for the site under review, and be mindful of how ground-water restoration processes might affect provisions of the long term surveillance plan.

The DOE implementation strategy for ground-water cleanup has been termed the Observational Approach. Implementation of the Observational Approach is discussed in the DOE 1993 "Technical Approach to Groundwater Restoration" (U.S. Department of Energy, 1993) and the DOE 1996 "Final Programmatic Environmental Impact Statement for the UMTRA Ground Water Project". This decision framework is implemented by the DOE through one or more site observational work plans that are provided for NRC review and comment on whether the stated approach appears viable for achieving compliance. The purposes of site observational work plans are to select a preliminary restoration strategy based on existing data, and to identify additional data collection needs. As data collection needs are met through further site characterization and model refinement, either the preliminary restoration strategy is supported, or a new strategy is selected. Once it is determined that remaining uncertainties can be managed as reasonable deviations, the final restoration strategy is presented in a Ground-Water Corrective Action Plan, which is submitted for NRC concurrence.

The purpose of this standard SRP is to aid NRC staff in the review of the following UMTRA Ground-Water Project documents that may be submitted by the DOE for NRC review:

(1) Site observation work plans

(2) Remedial action plans

(3) Ground-Water Corrective Action Plans

(4) Updates to long term surveillance plans.

Site observation work plans are precursors to corrective action plans. The DOE uses site observation work plans to summarize what is known about a site, identify needs for additional data, and document the decision process for selecting a specified restoration strategy. A first-draft site observation work plan for a Title I site will likely contain a summary of what is known about the site, a working strategy for restoration based on existing data, and identification of additional data needs. Successive iterations of site observation work plans will be more complete, with fewer needs for additional data, and will more closely approach a remedial action plan.

A complete corrective action plan provides detailed information on (1) preparing a hydrologic site conceptual model, (2) defining ground-water protection standards, (3) Identifying a restoration strategy selection, and (4) preparing a corrective action plan.

Completion of ground-water corrective actions may necessitate updates to the long term surveillance plan. Because ground-water restoration and ground-water compliance monitoring may not have been fully examined during review of the original long term surveillance plan.

1.0 SITE CHARACTERIZATION

1.1 Areas of Review

The staff shall review the characterization information, given the circumstances and life cycle of a particular site, and the nature of the document under review. The staff shall also evaluate regional and site-specific hydrologic information related to both the former processing site and the proposed disposal site if they are different. The hydrologic information shall include both surface-water and ground-water systems, along with any interrelations among those systems. Complete site characterization should include or reference the following:

(1) Site background data that include descriptions of:

- (a) The site history of mining and/or milling operations;
- (b) Surrounding land and water uses; and
- (c) Site meteorological data.

(2) Ground-water and surface-water hydrology data, including:

- (a) Descriptions of hydrogeology and ground-water conditions;
- (b) Estimation of hydraulic and transport properties for each hydrogeologic unit;
- (c) Descriptions of surface-water hydrology and estimations of ground-water and surface-water interactions; and
- (d) Assessment of potential for flooding and erosion.

(3) Information concerning geochemical conditions and water quality, including :

- (a) Identification of constituents of concern;
- (b) Determination of background ground-water quality;
- (c) Confirmation of proper statistical analysis;
- (d) Delineation of the nature and extent of contamination;
- (e) Identification of contaminant source terms;
- (f) Characterization of subsurface geochemical properties; and
- (g) Identification of attenuation mechanisms and estimation of attenuation rates.

(4) Human health and environmental risk evaluations.

1.2 Review Procedures

The level of effort necessary to adequately characterize a particular site depends on site-specific circumstances. For example, if a particular site has no ground-water contamination and tailings are disposed of off-site, there will be very little need for detailed site characterization in support of water resources protection. Conversely, at a site with an existing source of ground-water contamination, the site characterization must be sufficient to support selection of restoration strategies and to determine the level of risk to human health and the environment.

Because the appropriate level of site characterization is specific to the methods of tailings disposal and ground-water corrective action selected for a particular site, there is not a single acceptable approach to conducting a site characterization. As such, the reviewer shall:

(1) Thoroughly evaluate the characterization information using the acceptance criteria in SRP, but reserve final judgment until all sections of the application have been reviewed; and;

(2) Assess whether the level of detail and technical merit of the characterization are sufficient to support the proposals, assumptions, and assertions in the application that are used to demonstrate regulatory compliance.

1.3 Acceptance Criteria

Knowledge of the site is needed to evaluate the existing and potential contamination. This characterization information shall include a description of activities and physical properties that may affect water resources at the mill site. The site characterization will be acceptable if it meets the following criteria:

(1) It contains a description of the site that is sufficient to assess the environmental impact the former mill site may have on the surrounding area; the populations that may be affected by such impacts; and meteorological conditions that may act to transport contaminants offsite. An acceptable site description will contain the following specific information:

  (a) A site history that includes:

    (i) A list of the known leaching solutions and chemicals used in the milling process and their relative quantities in mill wastes. The list should also identify any constituent listed in 40 CFR Part 192, Appendix I that may have been disposed of in the tailings pile.

    (ii) A description of the wastes generated at the site during milling operations, waste discharge locations, types of retaining structures used (e.g.~~,~~ tailings piles, ponds, landfills), quantities of waste generated, and a chronology of waste management practices.

    (iii) A summary of the known impacts of the site activities on the hydrologic system and background water quality.

(iv) If applicable, descriptions of any human activities or natural processes unrelated to the milling operation that may have altered the hydrogeologic system. Such human activities include ground-water use, crop irrigation, mine dewatering, ore storage, municipal waste land filling, oil and gas development, or exploratory drilling. Natural processes include geothermal springs, natural concentration of soluble salts by evaporation, erosion processes, and ground-water/surface-water interactions.

(b) Information pertaining to surrounding land and water uses that includes:

(i) A general overview of water uses, locations, quantities of water available, and the potential uses to which quality of water is suited;

(ii) Definitions of the class-of-use category for each water source (e.g., drinking water, agricultural, livestock, limited use);

(iii) Identification of potential receptors of present or future ground-water or surface-water contamination; and

(iv) Descriptions of non-mill-related human activities or natural processes that may affect water quality or water uses (e.g., oil and gas development, municipal waste landfills, crop irrigation, drought, erosion, etc.).

Human water consumption is not the only water use that must be considered in the review. Any use that may bring someone into contact with the contaminated water must be considered when evaluating health hazards. For example, nonpotable, radon-contaminated water piped to a public lavatory could pose a substantial health hazard.

(c) Sufficient meteorologic data for the region, including rainfall and evaporation data in sufficient detail to assess projected water infiltration through the disposal cell.

Monthly averages are an acceptable means of presenting general meteorological conditions; however, the reviewer shall ensure that extreme weather conditions are adequately described.

(2) The ground-water and surface-water hydrology is described adequately to support predictions of likely contaminant migration paths; selection of monitor well locations; and, when ground-water contamination exists, selection of a restoration strategy. The following specific information is provided to support these objectives:

(a) A description of hydrogeologic units that may affect transport of contaminants away from the site via ground-water pathways.

(i) Hydrostratigraphic cross-sections and maps are included to delineate the geometry, lateral extent, thickness, and rock or sediment type of all potentially affected aquifers and confining zones beneath the processing and disposal sites. Data used to construct such maps are referenced and of adequate quality and quantity to support a technically defensible interpretation.

(ii) The hydrogeologic units that constitute the uppermost aquifer (where regulatory compliance will be evaluated) are identified. The uppermost aquifer is the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility's property boundary.

(iii) If local perched aquifers are found at the site, their presence is noted. These formations may cause contaminated water to be diverted around monitoring systems, or may be improperly interpreted as the uppermost aquifer. Any saturated zone created by uranium or thorium recovery operations would not be considered an aquifer unless the zone is or potentially is: (1) hydraulically interconnected to a natural aquifer; (2) capable of discharge to surface water; or (3) reasonably accessible because of migration beyond the vertical projection of the boundary, of the land by the government.

(iv) Unsaturated zones, through which contaminants may be conveyed to the water-bearing units, are described. This information is adequate to support the assumptions used in estimating the source term for contaminant transport pathways. This information includes identification of potential preferential flow pathways that are either natural (e.g., buried stream channels), or man-made (e.g., abandoned wells or mine shafts).

(v) Information on geologic characteristics that may affect ground-water flow beneath the former mill site is provided. Examples of pertinent geologic characteristics include identification of significant faulting in the area, fracture and joint orientation and spacing for the underlying bedrock, and geomorphology of soil and sedimentary deposits (e.g., fluvial, glacial, or volcanic deposits).

(iv) Hydraulic-head contour maps, of both local and regional scale, for the uppermost aquifer and any units connected hydraulically beneath the site are sufficient to determine hydraulic gradients, ground-water flow direction, and proximity to offsite ground-water users. These maps are based on static water level observations at onsite and regional wells. Several measurements are taken at each observation well (American Society of Testing and Materials Standards D4750, D5092, D5521, D5787, and D5978). These measurements are sufficiently spaced in time to capture water level fluctuations caused by seasonal changes or local pumping of ground water. Enough observation wells are sampled to produce an adequate water elevation contour map. The appropriate number of wells is dependent on the size of the site and the choice of contour interval. However, as a rough estimate, there is at least one observation well for each contour line on the map. A more detailed contour map (small contour interval) is produced for the site and surrounding properties. The level of detail used for the regional contour map may be limited by the number of observation wells available offsite. The reviewer shall bear in mind that calculations of hydraulic gradients from hydraulic head contour maps is only rigorously valid for horizontal flow in aquifers.

(b) Estimations of hydraulic and transport properties of the underlying aquifer.

Hydrogeologic parameters used to support the choice of a ground-water restoration strategy or to demonstrate compliance include hydraulic conductivity, saturated thickness of hydrogeologic units, hydraulic gradient, effective porosity, storage coefficient, and dispersivity. The reviewer shall consider the influence of each of these parameters on evaluating compliance with standards established pursuant to Part 40, Appendix A, and determine whether estimates for each parameter are reasonably conservative, based on the data provided.

(i) Hydraulic conductivity and storage coefficients are determined by conducting aquifer pump tests on several wells at the site. Pump test methods that are consistent with American Society of Testing and Materials standards for the measurement of geotechnical properties and for aquifer hydraulic tests are considered acceptable by the NRC. These American Society of Testing and Materials standards include D4044, D4050, D4104, D4105, D4106, D4630, D5269, D5270, D5472, D 5473, D5737, D5785, D5786, D5850, D5855, D5881, and D5912. Any other peer-reviewed method or commonly accepted practice for aquifer parameter estimation may be used. When curve fitting is used to analyze pump test data, deviations of observation data from ideal curves are explained in terms of likely causes (e.g., impermeable or recharge boundaries, leaky aquitards, or heterogeneities). When average hydraulic parameters are reported, the reviewer shall consider that many hydrogeologic parameters, including hydraulic conductivity, typically exhibit a log-normal distribution. Consequently, the geometric mean may be more representative of the overall conditions within a unit than the arithmetic mean.

(ii) Horizontal components of hydraulic gradient are estimated by measurement of the distance between contour intervals on hydraulic head contour maps. Vertical components of hydraulic gradient are estimated from head measurements in different aquifers or at different depths in the same aquifer.

(iii) Generally, analyses considering steady state conditions are acceptable unless site conditions indicate otherwise. If transient conditions are modeled, storage coefficients estimated from standard tests indicated in (i) above are used.

(iv) If contaminant transport is modeled, then longitudinal and transverse dispersivity values are either obtained from a tracer test or conservative values based on published literature are used. Because dispersivities depend on the size of the modeled region, the reviewer shall carefully compare the values for dispersivity used in the DOE's transport modeling with those values cited in survey studies such as Gelhar et al. (1992), and verify that they represent conservative estimates for the site.

(c) Estimation of ground-water/ surface-water interactions at sites with nearby streams, rivers, or lakes.

The location of surface-water bodies that are connected to the site ground-water flow system are identified. Surface-water elevations shall be used to help describe the site ground-water flow system if a stream or other surface-water body discharges into or drains the site ground-water flow system. Another acceptable approach is to evaluate hydraulic head contour based on data from monitor wells in the vicinity of streams.

(3) Geochemical conditions and water quality are characterized sufficiently to:

(a) Identify the constituents of concern.

Any chemical constituent that meets both of the following criteria must be listed as a constituent of concern:

(i) The constituent is reasonably expected to be in or derived from the tailings.

(ii) The constituent is listed in either 40 CFR Part 192, Appendix I or 40 CFR Part 192, Subpart A, Table I.

Table 1.1 provides a list of constituents commonly associated with uranium mill tailings (Smith, 1987). This list is based on a chemical survey performed by staff at 17 Title II sites.

Most of the constituents in 40 CFR Part 192, Appendix 1 are organic compounds that are not normally associated with uranium milling processes. The expected presence of organic compounds is assessed from knowledge of the chemicals used during the milling process or other materials that may have been disposed of in the tailings. If there is no record of organic compounds used in the process, screening tests for volatile and semivolatile organics are performed to confirm the absence of organic compounds in the tailings and ground water.

(b) Provide a determination of background (baseline) water quality.

Background water quality is defined as the chemical quality of water that would be expected at a site if contamination had not occurred from the uranium milling operation. When adequate site-specific baseline data cannot be obtained for identified constituents of concern, samples of adjacent, and up-gradient, uncontaminated, water are taken as proxies to onsite baseline samples.

Table 1.1 Common Uranium Mill Chemical Constituents

Inorganic Constituents	Organic Constituents
Arsenic	Carbon Disulfide
Barium	Chloroform
Beryllium	Diethyl Phthalate
Cadmium	2—Butanone
Chromium	1,2—Dichloroethane
Cyanide	Naphthalene
Lead	
Mercury	
Molybdenum	
Net Gross Alpha	
Nickel	
Radium-226 and -228	
Selenium	
Silver	
Thorium-230	
Uranium	

To determine acceptability of background water quality determination, the following information is provided:

(i) Maps are of sufficient detail and legibility to show the background monitoring locations.

(ii) Descriptions of sampling methods, monitoring devices, and quality assurance practices are provided. Examples of acceptable methods include those that are consistent with American Society of Testing and Materials Standards D 4448, D 4696, and D 4840. Other methods, if used, are properly referenced and justified.

(iii) When they exist, zones of differing background water quality are delineated. A discussion of the possible causes of these differing water quality zones is included (e.g., changes from geochemically oxidizing to reducing zones in the aquifer; changes in rock type across a fault boundary).

(iv) A table for each zone of distinct water quality, listing summary statistics (i.e., mean, standard deviation, and number of samples) for baseline water quality sampling for each constituent of concern, is provided.

(c) Confirm the proper use of statistical techniques for assessing water quality.

Statistical hypothesis testing methods used for: (i) establishing background water quality; (ii) establishing ground-water protection standards for compliance monitoring; (iii) determining the extent of ground-water contamination; and (iv) establishing the ground-water cleanup goals, are described in Appendix A and American Society of Testing and Materials Standard D6312.

(d) Define the extent of contamination.

A hazardous constituent is defined as a constituent that meets all three of the following tests:

(i) The constituent is reasonably expected to be in or derived from the byproduct material in the disposal area;

(ii) The constituent has been detected in the ground water in the uppermost aquifer; and

(iii) The constituent is listed in 40 CFR Part 192, Appendix I or 40 CFR Part 192, Subpart A, Table 1.

For each hazardous constituent the DOE determines the extent of contamination in ground water at the site. Ground-water contamination at uranium mill sites is usually limited to the uppermost aquifer. Maps showing the locations of sampling wells should be included, along with a discussion of sampling practices. The most useful way to present this information is on a map showing concentration contours for each hazardous constituent and water surface elevation contours. In this manner, the size, shape, source, and direction of movement can be readily examined by the reviewer.

The extent of contamination is delineated in three dimensions. This typically involves drilling a number of characterization wells and determining whether the water quality in each of these wells meets background water quality (i.e., null hypothesis) or whether the ground water is contaminated (i.e., alternative hypothesis). It may not be necessary to sample all hazardous constituents, to delineate the extent of contamination. Two or three indicator parameters (e.g., total dissolved solids, and chloride) might be selected. These indicators should be conservative—meaning that they are neither reactive, nor are they easily sorbed to soil—so that they provide a good indication of the maximum extent of contamination.

The transition from contaminated to uncontaminated ground water is often gradual. Thus, difficulty arises in determining where the contaminated water ends and the background water begins. The background data provide the easiest means for comparison of characterization well measurements to background measurements for the indicator parameters. The easiest method is to use the tolerance limit method to determine the upper limit for the range of background concentrations; characterization wells with concentrations above this limit can be assumed to have been affected by ground-water contamination.

Complications in delineating the extent of contamination arise at sites that have zones of differing water quality, or where on-site background water quality is not properly determined before discovery of ground-water contamination. Where zones of differing water quality are present, the reviewer shall verify that characterization wells are compared with the background sample from the appropriate water quality zone. Where on-site background water quality has not been properly determined, then up gradient or offsite samples are obtained.

The reviewer shall verify that the DOE has provided the following information to support determining the extent of contamination.

(i) A map or maps showing the distribution of surface wastes and contaminated materials at and near the site.

(ii) A map or maps showing the approximate shape and extent of ground-water contamination (e.g., concentration contour maps for indicator parameters in ground water).

(iii) Identification of any off-site sources of water contamination or other factors that may have a bearing on observed water quality.

(iv) Properly estimate the source term.

Existing sources of ground-water contamination are defined in terms of location and rate of entry into the subsurface. At some sites, the contaminant sources have been effectively eliminated through stabilization or removal of tailings piles. However, residual sources may still exist in contaminated subsurface soils at the site. For ground-water contamination that originates from an onsite tailings pile, the source term is determined based on the chemical properties of the leachate and the rate at which leachate is released from the disposal area. The level of review given to source term calculations is commensurate with the overall importance of source term estimations to the selection of the restoration strategy.

Source terms are reasonably correlated to the history of ore processing. All facilities from which leakage can occur are identified. Leaking constituents are identified based on the nature of the processing fluids. The volume of leakage is estimated in a realistic yet conservative manner. This can be done using water balance calculations, infiltration modeling, or seepage monitoring approaches.

When geochemical models are used to predict the fate and transport of existing contamination where the original source has been eliminated, the distribution of each hazardous constituent in place is taken as the source term.

(f) Characterize the subsurface geochemical properties.

To effectively model the fate and transport of contaminants in ground water, it is important to characterize the geochemical properties of the natural waters and the aquifer mineralogy.

Characterization of the underlying lithologies includes measurements of buffering capacity, total organic carbon, cation exchange capacity, and identification of the clay mineralogy. The general chemical characteristics of fluids within the lithologies are described by measurements of pH, temperature, dissolved oxygen, redox potential (Eh), buffering capacity, and the concentrations of major ions and trace metals.

(i) Aquifer geochemistry data are adequate to model the attenuation of contaminants. The values of the geochemical parameters used in transport models are justified. Acceptable parameter estimation methods include, direct measurement, use of a conservative bounding estimate, reference to literature values for similar aquifer conditions, and laboratory studies of aquifer materials.

(g) Identify contaminant attenuation mechanisms.

The major attenuation mechanisms that work to mitigate the effects of ground-water contamination are dilution in surrounding ground water, sorption of contaminants to the soil matrix, and immobilization of contaminants from geochemical and biochemical reactions.

Claims that contamination is reduced by dilution are supported by a sufficient technical basis. There are two mechanisms for dilution of a contaminant plume in ground water: dispersion and mixing. Dispersion is a process whereby contaminant plumes tend to spread out and become less concentrated as they are advected away from the source. Mixing is the result of uncontaminated water being added to the ground-water system through natural recharge, injection, or upward movement of water from underlying aquifers, which reduces the concentration of contaminants. Estimation of surface recharge or upward flow through leaky aquitards is either established from field measurements or conservative assumptions are used.

(i) The values of sorption coefficients are based on the nature of the constituent and site-specific geochemical conditions. The degree of sorption of contaminants to the soil matrix depends on the affinity of each constituent for the soil in a particular aquifer. Constituents that carry a positive charge, as do most trace metals in solution, are good candidates for cation exchange adsorption to clay and oxide surfaces. However, because surface charges of clays and oxides decrease with decreasing pH, the reviewer shall carefully examine claims of attenuation from cation exchange under low pH conditions. Organic contaminants tend to be hydrophobic and are strongly attenuated in soils that have high organic carbon content. Most contaminant fate and transport models quantify the affinity of contaminants for soil by use of a distribution coefficient or K_D. Batch or column equilibria experiments, using representative leachate and soil samples, are performed to support estimations of K_D for each hazardous constituent.

(b) Estimations of attenuation from geochemical or biochemical equilibrium reactions are accomplished by use of acceptable modeling software packages such as MINTEQA2 (Allison, et al., 1991) and PHREEQE (Parkhurst, et al., 1980). However, these packages are limited in that they do not consider transport of contaminants. Thus, results are only valid for reactions within a confined space (e.g., within the disposal cell). The reviewer shall determine that all model input parameters have sufficient technical bases and represent reasonably conservative estimations. Additionally, conclusions drawn from such models are supported by field observation; that is, they are consistent with site characterization data.

(ii) At sites where the contamination source has been effectively eliminated, monitoring data are used to assess attenuation of contaminants. If the contaminant source has been eliminated by surface reclamation, changes in the nature and extent of contamination over time are monitored. In such situations the center of mass of the contaminant plume moves along the direction of ground-water flow. The effects of dispersion are also observable over time as a decrease in peak concentrations near the center of the contaminant plume and a lateral spreading of the plume. If significant precipitation or adsorption is occurring, it is reflected in a decrease in the mass of contaminants in the aqueous phase.

1.4 Evaluation Findings

If the staff's review, as described in standard review plan results in the acceptance of the site characterization, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the site characterization at the __________________ uranium milling facility.

The DOE has provided an acceptable history of the site, including: (1) a description of leaching solutions and other chemicals used in the process and their relative quantities; (2) a description of the wastes generated at the site during the milling process, and the waste handling facilities; (3) a summary of the known impact of site activities on the hydrologic system and water quality; and (4) a description of non-milling-related activities that may have altered the hydrologic system.

The DOE has provided acceptable information pertaining to the surrounding land and water use including: (1) an overview of water uses, quantity available, and potential uses to which the water is suited; (2) definitions of the class-of-use category of each water source; (3) identification of potential receptors of ground-water or surface-water contamination; (4) assessment of variations in dilution effects of stream flow on contaminants; and (5) assessments of the effects of meteorological conditions on erosion, infiltration, and water-table elevation.

The DOE has provided acceptable meteorologic data, including : (1) wind speed and direction; (2) rainfall; and (3) evaporation data, to allow an evaluation of potential impacts of the meteorologic conditions on disposal cell performance.

The ground-water and surface-water hydrology is acceptably described, including: (1) geometry, lateral extent, and thickness of potentially affected aquifers and confining units; (2) a determination of which aquifers constitute the uppermost aquifer where regulatory compliance will be evaluated; (3) descriptions of the unsaturated units that convey hazardous constituents to the water-bearing units; (4) maps of acceptable detail showing the relative dimensions and locations of hydrogeologic units that have been impacted by milling activities; (5) information on geologic characteristics that may affect ground-water flow beneath the site; and (6) hydraulic head contour maps of both local and regional scale for the uppermost aquifer beneath the site.

The estimation of hydraulic and transport properties is acceptable and includes: (1) hydraulic conductivity and storage coefficients determined by conducting aquifer pump tests on several wells; (2) determination of hydraulic gradients using hydraulic head contour maps; (3) calculations of storage coefficients, as applicable; and (4) longitudinal and transverse dispersivities, as appropriate. The evaluation of ground-water/ surface-water interactions with nearby streams, rivers, or lakes is acceptable.

Geochemical conditions and water quality are acceptably analyzed, including identification of constituents of concern that are reasonably expected to be derived from the tailings. Each constituent of concern is found in 40 CFR Part 192, Appendix I or 40 CFR Part 192, Subpart A, Table 1. The DOE has made an acceptable determination of baseline water quality, including: (1) maps of appropriate scale and legibility; (2) descriptions of sampling methods, monitoring devices, and quality assurance practices; (3) where applicable, delineation of zones of differing water quality and their possible origin; and (4) a table of summary statistics for each zone of differing quality. The applicant has provided an acceptable delineation of the extent of contamination supported by appropriate samples, maps of surface wastes and contaminated materials, maps of the approximate shape and extent of ground-water contamination, and identification of any offsite sources of water contamination. The description of the source term is acceptable and includes not only mill tailings constituents but those contaminants that might mobilize by contact with tailings leachate.

The characterization of the subsurface geochemical properties is acceptable. Attenuation mechanisms have been described including the technical bases for determining that contamination will be reduced by dilution, sorption on the soil matrix, or geochemical or biochemical reactions. The DOE has provided direct measurements in support of attenuation of contaminants where the source has been eliminated by surface reclamation.

On the basis of the information provided in the application and the detailed review conducted of the site characterization for the _______________ uranium milling facility, the NRC staff has concluded that the information is acceptable and is in compliance with 40 CFR 192.02 (c), which requires the NRC to establish a list of hazardous constituents, concentration limits, a point of compliance, and a compliance period; 40 CFR Part 192, Subpart A, Table 1, which provides a table of concentration limits for certain constituents when they are present in ground water above background concentrations.

1.5 References

American Society for Testing and Materials Standards

D4044 Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifiers.

D4050 Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems.

D4104 Standard Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests).

D4105 Standard Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method.

D4106 Standard Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method.

D4448 Standard Guide for Sampling Groundwater Monitoring Wells.

D4630 Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test.

D4696 Standard Guide for Pore-Liquid Sampling from the Vadose Zone.

D4750 Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).

D4840 Standard Guide for Sampling Chain-of-Custody Procedures.

D5092 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.

D5269 Standard Test Method for Determining Transmissivity of Nonleaky ConfinedAquifers by the Theis Recovery Method D5270-96 Standard Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers.

D5472 Standard Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well.

D5473 Standard Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined.

D5521 Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers.

D5737 Standard Guide for Methods for Measuring Well Discharge.

D5785 Standard Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test).

D5786 Standard Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems.

D5787 Standard Practice for Monitoring Well Protection.

D5850 Standard Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells.

D5855 Standard Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well.

D5881 Standard Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug).

D5912 Standard Test Method for (Analytical Procedure) Determining HydraulicConductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug).

D5978 Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells.

D6312-98 Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs.

Allison, J.D., D.S. Brown, and K.J. Novo-Gradac, 1991, MINTEQA2/PRODEFA2, A Geochemical Assessment Model for Environmental Systems: Version 3.0 User's Manual. Environmental Protection Agency Publication EPA/600/3-91/021, 1991.

Environmental Protection Agency, 40 CFR Part 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings.

Gelhar, L.W., C. Welty, and K.R. Rehfeldt, 1992, A critical review of data on field-scale dispersion in aquifers. Water Resources Research 28(7), 1992.

NRC, 1996, Staff Technical Position; Alternate Concentration Limits for Title II Uranium Mills, January 1996.

Parkhurst, D.L., Thorstensen, and L.N. Plummer, 1980, PHREEQE-A Computer Program for Geochemical Calculations. U.S. Geological

Survey, Water Resources Investigation 80-96, 1980.

Smith R.D. 1987, Nuclear Regulatory Commission, “Sampling of Uranium Mill Tailings Impoundments for Hazardous Constituents”, Memorandum, February 9, 1987, Division of Waste Management, Nuclear Regulatory Commission.

2.0 GROUND-WATER PROTECTION STANDARDS

2.1 Areas of Review

Ground-water protection standards are established for each hazardous constituent. The staff will review the technical basis that the DOE has presented for the following elements of acceptable ground-water protection standards:

(1) The list of hazardous constituents;

(2) A description of the point of compliance;

(3) Ground-water Protection Standards for hazardous constituents may be either:

(a) Background concentration limit

As defined in 40 CFR 192.02 (c)(3)(i)(A) the background concentration limit is the background concentration.

(b) Maximum concentration limit.

Maximum concentration limits are identified in 40 CFR Part 192, Subpart A, Table 1.

(c) Alternate concentration limit

Alternate concentrations limits are established as described in 40 CFR 192.02(c)(3)(ii).

(d) Supplemental Standards

Supplemental standards are established as described in 40 CFR Parts 192.21 and 192.22.

2.2 Review Procedures

The reviewer shall examine the ground-water protection standards to verify that they have been defined consistent with the acceptance criteria. Specifically, the reviewer shall:

(1) Verify that the DOE has identified all constituents of concern that are present in the tailings leachate.

(2) Verify that the point of compliance has been properly delineated.

(3) Evaluate whether the proposed concentration limits for each ground-water Protection Standard are within a range that is reasonably expected to represent background concentrations; or, if any alternate concentration limits or supplemental standards are proposed, verify that the appropriate evaluations have been presented in accordance with 40 CFR Parts 192.02 and 192.21 and 192.22.

2.3 Acceptance Criteria

Ground-water protection standards establish a concentration limit for each hazardous constituent, at the point of compliance. The development of ground-water protection standards will be acceptable if it meets the following criteria:

(1) Hazardous constituents are identified.

(2)A point of compliance is established in accordance with 40 CFR 192.02(c)(4).

The point of compliance is the location where the ground water is monitored to determine compliance with the ground-water protection standards. The objective in selecting the point of compliance is to provide the earliest practicable warning that the impoundment is releasing hazardous constituents to the ground water. The point of compliance must be selected to provide prompt indication of ground-water contamination on the hydraulically downgradient edge of the disposal area. The point of compliance is defined as the intersection of a vertical plane with the uppermost aquifer at the hydraulically downgradient limit of the waste management area.

When tailings are disposed of on site, the NRC generally interprets the downgradient limit of the waste management area to be the edge of the reclaimed tailings side slopes. However, it is not recommended that DOEs be required to compromise the cover integrity to install monitoring wells at the actual edge of the reclaimed tailings.

(3) A concentration limit is specified for each of the hazardous constituents.

(a) Background concentration limit

Proper statistical methods, as discussed in Appendix A, are used to determine the expected range of naturally occurring background (baseline) concentrations for each hazardous constituent.

(b) Maximum Concentration Limits

Maximum concentration limits may be established for each hazardous constituent identified in 40 CFR Part 192, Subpart A, Table 1 and at the concentrations given in the table, if the background level of the constituent is below the value given in the table.

Alternate Concentration Limits

Within 40 CFR 192.02(c)(3)(ii), the option for ACLs is established. ACLs are established on a site-specific basis after considering remedial or corrective actions to achieve MCLs or background, provided it is demonstrated that the constituents will not pose a substantial present or potential hazard to human health or the environment, as long as the ACLs are not exceeded. Factors are outlined in 40 CFR 192.02(c)(3)(ii)(B)(1 and 2). The criteria for the hazard assessment for ACLs is outlined in Section 3.0 of this SRP.

Supplemental Standards

Criteria for applying supplemental standards is detailed in 40 CFR 192.21 and 192.22. Supplemental standards may be applied when it is determined that the following circumstances exist:

(a) Remedial actions required under 40 CFR Part 192 Subpart A or B would pose a clear and present risk of injury to workers or to members of the public, notwithstanding reasonable measures to avoid or reduce risk.

(b) Remedial actions to satisfy the cleanup standards for land and ground water directly produce harm that is clearly excessive compared to the health and environmental benefits, now or in the future. A clear excess of health and environmental harm, is harm that is long term, manifest, and grossly disproportionate to health and the environmental benefits that may reasonably be anticipated.

(c) The estimated cost of remedial action is unreasonably high relative to the long-term benefits, and the residual radioactive materials do not pose a clear present or future hazard.

(d) The cost of a remedial action for cleanup of a building is clearly unreasonably high relative to the benefits.

(e) There is no known remedial action.

(f) The restoration of ground water is technically impracticable from an engineering perspective.

(g) The ground water meets the definition of *limited use groundwater* per 40 CFR 192.11(e). The definition of a *limited use groundwater*, per 40 CFR 192.11(e), is defined as: "*groundwater that is not a current or potential source of drinking water because (1) the concentration of total dissolved solids is in excess of 10,000 mg/l, or (2) widespread, ambient contamination not due to activities involving residual radioactive materials from a designated processing site exists that cannot be cleaned up using treatment methods reasonably employed in public water systems, or (3) the quantity of water reasonably available for sustained continuous use is less than 150 gallons per day*".

(h) Radionuclides other than radium 226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials

When one or more of the criteria applies, the remedial alternative that comes as close to meeting the applicable standard under 40 CFR 192.02 (c)(3) as is reasonably achievable should be implemented.

2.4 Evaluation Findings

If the staff's review results in the acceptance of the site ground-water protection standards, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the ground-water protection standards at the _________________ uranium milling facility.

The DOE has acceptably identified the hazardous constituents and has established acceptable concentration limits and cleanup standards . Established background levels are acceptable. Acceptable statistical methods have been used to establish the concentration limits. If alternate concentration limits have been requested, the DOE has acceptably supported the request with appropriate data and calculations. The DOE has established an acceptable point of compliance at the edge of the tailings impoundment on the down-gradient direction of hydraulic flow.

On the basis of the information provided in the application and the detailed review conducted of the ground-water protection standards for the _______________ uranium milling facility, the staff has concluded that the information is acceptable and is in compliance with 40 CFR 192.02, which requires the NRC to establish a list of hazardous constituents, concentration limits, a point of compliance, and a compliance period; 40 CFR Parts 192.02, 192.21, 192.22 and 40 CFR 192, Subpart A, Table 1, which allows use of maximum concentration limits, alternate concentration limits, and supplemental standards.

2.5 References

Environmental Protection Agency, 40 CFR Part 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings.

3.0 HAZARD ASSESSMENT FOR ALTERNATE CONCENTRATION LIMITS

3.1 Areas of Review

Alternate concentration limits must be protective of human health and the environment at the point of exposure. Alternate concentration limits which "are not protective of human health and the environment" will not satisfy the alternate concentration limit framework.

The staff shall review the following elements of alternate concentration limit assessments:

(1) Identification of a point of exposure;

(2) Characterization of the hazardous constituent source term and the extent of ground-water contamination;

(3) Assessment of hazardous constituent transport in the ground water and hydraulically connected surface waters, and their adverse effects on water quality, including present and potential health and environmental hazards;

(4) Assessment of human and environmental exposure to hazardous constituents, including the cancer risk and other health and environmental hazards; and

(5) A demonstration that hazardous constituent concentrations will not pose substantial present nor potential hazards to human health and the environment at the point of exposure.

(6) Assessment of potential remedial alternatives.

3.2 Review Procedures

The reviewer shall examine the information and assessments provided for establishing alternate concentration limits to make the following determination.

(1) The hazardous constituent source term has: (a) been characterized; (b) is sufficient to provide a defensible estimate of the types, characteristics, and release rates of hazardous constituents that have been or are anticipated to be released from the source term; and (c) the extent of ground-water contamination at the site has been defined.

(2) The rates and directions of hazardous constituent migration and transport in the ground water and hydraulically connected surface waters have been adequately determined.

(3) The pathways for human and environmental exposure to hazardous constituents have been identified, and exposure magnitudes and effects, including the cancer risk, have been acceptably evaluated.

(4) The alternate concentration limits proposed at the point of compliance are at a level that will allow the consituent concentrations to be protective of human health and the environment at the point of exposure, considering the attenuation capacity of the aquifer between the point of compliance and

the point of exposure, there will be no adverse effects on the ground water or on surface-water quality that would cause substantial health or environmental hazards at or beyond the point of exposure location(s).

(6) Remedial alternatives have been adequately evaluated and factors such as the length of time to reach the standard, applicability to the site conditions, and cost comparisons have been assessed.

3.3 Acceptance Criteria

The hazard assessments for alternate concentration limits will be acceptable if they meet the following criteria:

(1) A hazard assessment is performed, that is in accordance with 40 CFR 192.02. The assessment addresses the present and potential health and environmental hazards, including the cancer risk caused by human exposure to radioactive constituents and other health hazards that may be caused by the chemical toxicity of constituents.

The acceptability of the proposed alternate concentration limit values is based on a finding that the constituent will not pose a substantial present nor potential hazard to human health and the environment as long as the alternate concentration limit is not exceeded. The use of previously established and documented health-based constituent concentration limits in the hazard assessment is used as a basis for establishing alternate concentration limit values at specific sites, or such values are determined for constituents for which health-based concentration limits have not been established.

(2) The point of exposure is identified.

The point of exposure is defined as the location(s) at which people, wildlife, or other species could reasonably be exposed to hazardous constituents from the ground water. For example, the point of exposure may be represented by the location where one or more domestic wells could be constructed and might withdraw contaminated ground water, or it may be represented by springs, rivers, streams, or lakes into which contaminated ground-water might discharge. In most cases, the point of exposure is located at the downgradient edge of land that will be held by either the Federal Government or the State for long-term institutional control. The concept of a point of exposure is used to assess the potential hazard to human health and the environment. Alternate concentration limits for hazardous constituents are established at the point of compliance. The point of exposure may be situated at some distance from the point of compliance, allowing the hazardous constituent concentrations to diminish through dispersion, attenuation, or sorption within the aquifer. As a result, an alternate concentration limit may be set at a concentration that is higher than a limit that would be protective of human health and environment at the point of compliance location, as long as the hazardous constituent concentration at the point of exposure protects human health and environment.

A distant-point of exposure could be justified, on the basis that land ownership by DOE would ensure that ground water from the contaminated aquifers between the disposal site and the point of exposure would not be used. In some rare instances, a distant-point of exposure may be established without invoking land ownership or long-term custody. Land ownership or long-term custody will not be an issue for establishing a distant point of exposure, if the possibility of human exposuer is effectively impossible. When ground water is inaccessible or unsuitable for use, human exposure is considered effectively impossible.

(3) The hazardous constituent source term and the extent of ground-water contamination are characterized.

Characterization of the contaminant source(s) and their extent provides the source term for contaminant transport assessments. The source characterization provides reliable estimates of the release rates of hazardous constituents as well as constituent distributions.

The source term characterization provides relevant information about the facility, including: (a) the uranium recovery processes used; (b) types and quantities of the reagents used in milling; (c) milled-ore compositions; and (d) historical and current waste management practices. This information is considered, in conjunction with the physical and chemical composition of the waste and the type and distribution of existing contaminants, to characterize the source term and evaluate future hazardous constituent release into the ground water (e.g., location of waste discharges, retaining structures for wastes, and waste constituents).

Depending on the hazardous constituents present, additional information on them and their properties is provided including: (a) density, solubility, valence state, vapor pressure, viscosity, and octanol-water partitioning coefficient; (b) presence and effect of complexing ligands and chelating agents, to the extent that constituent mobility may be enhanced; (c) potential for constituents to degrade because of biological, chemical, and physical processes; and (d) constituent attenuation properties, considering such processes as ion exchange, adsorption, absorption, precipitation, dissolution, and ultrafiltration.

At sites with well-defined contaminant plumes, the spatial distribution of the various hazardous constituents is specified. This information calibrates contaminant transport models and supports evaluations of whether humans and environmental populations are being exposed to elevated concentrations of hazardous constituents. Characterization of the contamination extent includes: (a) the type and distribution of hazardous constituents in the ground water and contamination sources; (b) the monitoring program used to delineate and characterize hazardous constituent distribution; and (c) documentation of the sampling, analysis and quality assurance programs followed in the implementation of the site monitoring programs. Such information is used to assess present human and environmental population exposure to elevated concentrations of hazardous constituents, calibrate contaminant transport models, and evaluate projected future exposures.

(4) The hazardous constituent transport in ground water and hydraulically connected surface water and the adverse effects on water quality, including the present and potential health and environmental hazards, are assessed.

The hydrogeologic and contaminant transport assessment provides and documents estimates of projected contaminant distribution, including contaminant transport and degradation and attenuation mechanisms between the point of compliance and the point of exposure. The assessment generally characterizes and provides information on: (a) site hydrogeologic characteristics, including ground-water flow direction and rates; (b) background water quality; and (c) estimated transport rates, geochemical attenuation, and concentrations of hazardous constituents in the ground water and hydraulically connected surface water.

All likely and significant pathways of hazardous transport in ground water and surface water should be identified and assessed. Estimated hazardous constituent concentrations and projected distributions are either best estimates or reasonably conservative representations of the rate, extent, and direction of constituent transport.

Projections should be calibrated based on site-specific information. When there is great uncertainty in the attenuation-rate estimate, the DOE may rely on measurements of constituent concentrations at the point of compliance and the point of exposure over a sufficient time period, before alternate concentration limits are established, to verify the projected attenuation rate.

When projecting (modeling) the concentrations of hazardous constituents at the POE, the staff has found it acceptable to project impacts at the POE over at least a 1,000 year time frame. This is consistent with the design standard of 40 CFR 192.02 which states that "*control of residual radioactive materials and their listed constituents shall be designed to be effective for up to one thousand years, to the extent reasonably achievable, and in any case, for a least 200 years.*"

(5) An assessment of human or environmental exposures to hazardous constituents, including cancer risk and other health and environmental hazards, is provided.

The exposure assessment identifies the maximum levels permissible at the point of compliance that are protective of human health and the environment at the point of exposure by evaluating human and environmental exposure to hazardous constituents and then demonstrating that the proposed alternate concentration limits do not pose substantial present nor potential hazards to human health or the environment.

The exposure assessment at specific sites evaluates health and environmental hazards using water classification and water use standards, and existing and anticipated water uses. Agricultural, industrial, domestic, municipal, environmental, and recreational water uses, as they pertain to the site, are considered. The assessment identifies and evaluates hazardous constituent exposure pathways and makes projections of human and environmental population response based on the projected constituent concentrations, dose levels, and available information on the radiological and chemical toxicity effects of hazardous constituents. The assessment addresses the underlying assumptions and variability of the projected health and environmental effects.

The human exposure assessment is evaluated primarily on the basis of the extent to which people are using, and are likely to use, contaminated water from the site. Site-specific water uses are determined on the basis of the following considerations: (a) ground-water quality in the site area and present water uses; (b) statutory or legal constraints and institutional controls on water use in the site area; (c) Federal, State, or other ground-water classification criteria and guidelines; (d) applicable water use criteria, standards, and guidelines; and (e) availability and characteristics of alternative water supplies.

The human exposure assessment considers two potential exposure pathways: (a) ingestion of contaminated water and (b) ingestion of contaminated foods. The assessments distinguish between health effects associated with threshold and nonthreshold constituents. Mutagenic, teratogenic, and synergistic effects are considered in the analysis, if applicable, based on toxicological testing, structure-activity relationships, or epidemiological studies. Other pathways that may impact human health, such as dermal contact and inhalation, are also to be considered, but need not always be assessed, unless it is determined that these exposures could result in significant hazards to human health or the environment.

The assessment of adverse effects associated with present and potential human exposure to hazardous constituents should be based on the exposure pathways characterization. The human exposure assessment includes: (a) classification of affected water resources; (b) assessment of existing and potential water uses; (c) evaluation of the likelihood that people will be exposed to hazardous constituents; and (4) evaluation of adverse effects associated with exposure to hazardous constituents, including assessment of the permanence and persistence of adverse effects.

Assessments of the probability of human exposure are often difficult to establish quantitatively. Consequently, defensible qualitative estimates are often necessary, and can be characterized as either:

(a) Reasonably likely - when exposure has or could have occurred in the past, or available information indicates that exposure to contamination may reasonably occur during the contamination period, or

(b) Reasonably unlikely - when exposure could have occurred in the past, but will probably not occur in the future, either because initial incentives for water use have been removed, or because available information indicates that no incentives for water use are currently identifiable, based on foreseeable technological developments.

Information in support of the exposure assessment should be supplied, or relevant information and studies; such as those available from the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurement, for the effects of radioactivity, and EPA's Integrated Risk Information System, for chemical-toxicity effects, should be referenced. Alternatively site-specific information provided in previous reports, such as the license application or the environmental report, can be referenced. A technical basis to establish a reasonable assurance that the proposed alternate concentration limits do not pose a hazard to human health or the environment should be provided for each constituent for which an alternate concentration limit may be established.

Exposure determinations should consider existing and potential water uses. Potential uses include those uses that are reasonably sure to occur (i.e., anticipated use) and uses that are compatible with the untreated background water quality (i.e., possible use). Past uses may be included as existing or potential uses.

Water resource classification of existing and potential water use should include: (a) domestic and municipal drinking-water use; (b) fish and wildlife propagation; (c) special ecological communities; and (d) industrial, agricultural, and recreational uses. The classification of existing and potential uses of water at the facility should be consistent with Federal, State, and local water-use inventories.

Water yields, costs for development of alternate water supply sources, and legal, statutory, or other administrative constraints on the use and development of the water resources should be verified.

The cancer risk should be evaluated for individual constituents, including radioactive and carcinogenic chemicals, and compared with the maximum permitted risk level. The health effects of non-radioactive and non-carcinogenic constituents that are chemically toxic will be evaluated considering their risk-specific dose levels, and for some chemicals that have threshold effects, it will be necessary to calculate a Hazard Index using the reference doses. The Hazard Index is the ratio of calculated intake to the risk-reference dose, and an acceptable Hazard Index must be less than unity.

Reasonably conservative or best estimates of potential health effects caused by human exposure to hazardous constituents should include an assessment of potential health hazards for each constituent for which an alternate concentration limit is proposed, based on comparisons of existing and projected constituent concentrations with appropriate exposure limits and dose-response relationships from available literature. This assessment of potential health hazards should include the maximum concentration limits, risk-reference doses, or risk-specific doses. Risk-reference doses are the amounts of toxic constituents to which humans can be daily exposed without suffering any adverse effect. Risk-specific doses are the amounts of proven or suspected carcinogenic constituents to which humans can be daily exposed, without increasing their risk of contracting cancer, above a specified risk level.

Maximum concentration limits, risk-reference doses, and risk-specific doses for most hazardous constituents in uranium mill tailings can be obtained from EPA. The risk-reference dose and risk-specific dose assessment assume a human mass of 70 kg (154 pounds) and consumption of 2 liters of water per day (0.53 gallon/day). More stringent criteria may apply if sensitive populations are exposed to hazardous constituents. Maximum concentration limits, Risk-reference doses, and/or risk-specific doses, can be used to show compliance with the risk level and Hazard Indices. In the absence of applicable maximum concentration limits, risk-reference doses, or risk-specific doses, a technical basis for the risk assessment can base dose-response relationships on literature searches or toxicological research. The exposure analysis should distinguish between threshold (toxic) and non-threshold (carcinogenic) effects associated with human exposure, as well as teratogenic, fetotoxic, mutagenic, and synergistic effects.

The cumulative effects of human exposure to hazardous constituents for which alternate concentration limits are proposed and other constituents present in contaminated ground water will be maintained at a level adequate to protect public health. The combined effects from both radiological and non-radiological constituents should be considered.

Proposed human exposure levels should be reasonably conservative, defensible, and sufficiently protective of human health to avoid a substantial present or potential hazard to people for the estimated duration of the contamination. When considering the potential for health risks from human exposure to known or suspected carcinogens, it is acceptable if alternate concentration limits are established at concentration levels which represent an excess lifetime risk, at a point of exposure, to an average individual no greater than between 10^{-4} and 10^{-6}.

Potential responses of environmental or nonhuman populations to the various hazardous constituents are assessed if such populations can realistically be exposed to contaminated ground water or hydraulically connected surface water. Terrestrial and aquatic wildlife, plants, livestock, and crops are included in the assessment. In the absence of available information that readily may be used to demonstrate that there will be no substantial environmental impacts caused by ground-water contamination from the site, the exposure assessment provides: (a) inventories of potentially exposed environmental populations; (b) recommended tolerance or exposure limits; (c) contaminant interactions and their cumulative effects on exposed populations; (d) projected responses of environmental populations that result from exposure to hazardous constituents; and (e) anticipated changes in populations, independent of the hazardous constituent's exposure. Alternatively, DOE demonstrates that environmental hazards are not anticipated, because exposure will not occur.

The potential for adverse effects, such as: (a) contamination-induced biotic changes, (b) loss or reduction of unique or critical habitats, and (c) jeopardizing endangered species should be described. Aquatic wildlife effects are evaluated by comparing estimated constituent concentrations with Federal and State water-quality criteria. Consultation with the U.S. Fish and Wildlife Service is required under the Endangered Species Act, if an endangered or threatened species is found on the site, or is believed to inhabit the site.

Terrestrial wildlife exposure to constituents through direct exposure and food-web interactions should be considered.

Agricultural effects from both direct and indirect exposure pathways, crop impacts, reduced productivity, and bioaccumulation of constituents should be considered. Reasonably conservative estimates of constituent concentrations are compared with Federal and State water-quality criteria to estimate agricultural effects associated with constituent exposure. Additionally, crop exposures through contaminated soil, shallow ground-water uptake, and irrigation, along with livestock exposure through direct ingestion of contaminated water and indirect exposure through grazing, should be assessed.

When appropriate, the hazard assessment considers potential damage to physical structures (e.g., from corrosiveness), that may result from exposure to the hazardous constituents in ground water and hydraulically connected surface water. Alternatively, DOE demonstrates that damage to physical structures is not anticipated, because the exposure will not occur.

For physical structures, such as foundations, underground pipes, and roads, the reviewer ensures that estimated constituent concentrations will not result in any significant degradation or loss of function as a result of contamination exposure.

(6) An adequate assessment of alternative remedial actions has been provided.

In compliance with 40 CFR 192.02(c)(3)(ii)(A) remedial or corrective actions to achieve must be considered to achieve the either background concentration levels or the concentrations in 40 CFR Part 192, Subpart A, Table 1. Remedial or corrective actions must be alternatives that could realistically be applied at the site. The evaluation of alternatives should include the time to reach the appropriate concentration levels, applicability of the remedial technology to the site conditions, and cost.

The costs and benefits of each of the corrective action alternative should be considered. It may not be necessary in some cases to select and adopt the most stringent alternative if it can be demonstrated that the cost of implementing such an alternative is too high compared with the expected benefits. The ground-water corrective-action alternative assessments should ensure that: (a) a complete range of reasonable alternative corrective actions have been identified; (b) the identified corrective actions are feasible and appropriate to reduce constituent concentrations at the site; (c) the corrective actions have been designed to optimize their effectiveness; and (d) an objective comparison of the costs and benefits associated with the corrective actions is complete.

Corrective-action alternatives should be based on cleanup goals that are at or below the concentration limit determined by the hazard assessment to be protective of human health and the environment. A reasonable range of alternative goals should be evaluated (usually at least three). The goals should be (a) meaningfully different, (b) reasonably attainable by practicable corrective action, and (c) at or below the level identified in the hazard assessment.

Different corrective actions are currently in operation at uranium mill sites and Title I sites. These corrective actions, their results, and their application at other sites can serve as the basis for DOEs selection of a corrective-action program. Projections of hazardous, constituent concentrations at specific corrective-action measures could be based on present experience and data obtained from the implementation of such measures at other sites.

The corrective actions should be selected and designed to optimize the effectiveness in reducing hazardous constituent concentrations. This may be demonstrated with backup calculations that provide approximations of the effects of the proposed actions on the ground-water quality under the site-specific hydrogeologic conditions.

The direct and indirect benefits of implementing each of the identified corrective actions should be compared with the costs of performing (or not performing) such measures. The cost estimates include consideration of costs for design, operation, maintenance and decommissioning. The reviewer verifies estimates of the current and projected value of pre-contaminated water resources, based on water rights, availability of alternative water supplies, and projected water-use demands. The reviewer generally considers the value of potentially contaminated water resources as equal to either the cost of domestic or municipal drinking-water supplies, or the cost of supplied water to replace the contaminated resources. The absence of alternative water supplies increases the relative value of potentially contaminated water resources. The adequacy of the benefits assessment is similarly evaluated, considering the avoidance of adverse health effects, value of pre-contaminated ground-water resources, prevention of land-value depreciation, and benefits accrued from performing the corrective action.

3.4 Evaluation Findings

If the staff's review, as described in this standard review plan, results in the acceptance of the site hazard for alternate concentration limit evaluations, the following conclusions may be presented in the TER.

The NRC has completed its review of the site hazard assessment for alternate concentration limit evaluations at the _________________ uranium milling facility.

The DOE has performed an acceptable hazard assessment by considering present and potential health and environmental hazards, including cancer risk by human exposure to radioactive constituents and other health hazards resulting from the chemical toxicity of the constituents. The point of exposure has been identified and is acceptably sited at the downgradient edge of the affected land. When a distant point of exposure is used, written assurance has been secured, either by the DOE or NRC, that the appropriate Federal or State agency will accept the transfer of the specific property, including land in excess of that needed for tailings disposal. The hazardous constituent source term and the extent of ground-water contamination have been acceptably characterized. The transport of the hazardous constituent in ground water and surface water has been defined and any adverse effects on water quality, including present and future, have been assessed. The cancer risk and other health and environmental hazards from human or environmental exposures to hazardous constituents have been evaluated acceptably including: (a) identification of maximum levels permissible at the point of compliance; (b) evaluation of health and environmental hazards using water classification and use standards and existing and anticipated water uses; (c) appropriate consideration of impact, based on site-specific water uses; (d) consideration of ingestion of contaminated water and food; (e) consideration of response of environmental and nonhuman populations to the various hazardous constituents including terrestrial and aquatic wildlife, plants, livestock, and crops; and (f) consideration of potential damage to physical structures.

On the basis of the information provided in the application and the detailed review conducted of the site hazard assessment for alternate concentration limit evaluations for the _______________ uranium milling facility, the staff has concluded that the information is acceptable and is in compliance with 40 CFR 192.02.

3.5 References

Environmental Protection Agency, 40 CFR Part 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings.

4.0 GROUND-WATER CORRECTIVE ACTION AND COMPLIANCE MONITORING PLANS

4.1 Areas of Review

The staff shall review any ground-water Corrective Action Plan. For review of some information, the reviewer may use review procedures in other chapters of this standard review plan. The following are specific portions of a Corrective Action Plan to be reviewed.

(1) Selection of a ground-water compliance strategy,

(2) The remedial action design and implementation plan,

(3) Waste management practices,

(4) Institutional controls, and

(5) Ground-water monitoring plans.

4.2 Review Procedures

The ground-water compliance strategy shall be examined by the reviewer considering the previously reviewed hydrologic and geochemical site characterizations and ground-water protection standards. Requirements of 40 CFR 192.03 include that corrective action must be implemented as soon as is practicable, and result in conformance with the established concentration limits. 40 CFR Part 192.12 allows the DOE to choose between active remediation and natural flushing alternatives, and requires that a program be put in place to monitor compliance with restoration goals. Regulations do not provide any specific requirement for the design and operation of the ground-water remedial action program. In fact, 40 CFR 192.20 states that protection of water should be considered on a case-specific basis, drawing on hydrological and geochemical surveys, and other relevant data

The reviewer shall examine corrective action plans and compliance monitoring plan information to verify the following:

(1) The selected ground-water compliance strategy is likely to result in timely compliance with established standards.

(2) The DOE specifies a timetable for meeting minimum performance goals as an indication that the remedial action is working.

(3) The corrective action design and the implementation plan are appropriate for the site characteristics, and clearly defined restoration cleanup standards have been defined.

(4) Waste management practices are in compliance with environmental protection regulations.

(5) Institutional controls during the restoration period are sufficient to prevent significant hazards to human health and the environment.

(6) The ground-water monitoring system is sufficient to verify the performance of the selected restoration strategy, and to monitor the long-term performance of any onsite tailings disposal cells.

4.3 Acceptance Criteria

Regulation 40 CFR 192.04 requires that if the ground-water protection standards are found or projected to be exceeded, a corrective action program shall be placed into operation as soon as is practicable, and in no event later than 18 months after a finding of exceedance. Unless otherwise directed by the Commission, before putting the program into operation, the DOE shall submit the supporting rationale for the proposed corrective action program. The objective of the program is to return hazardous constituent concentration levels in ground water to the concentration limits set as standards.

The corrective action should result in conformance with the established concentration limits, address either removing the hazardous constituents or treating them in place, and include a program to monitor compliance with cleanup standards. Regulations do not require any specific designs or methods to be used for the ground-water corrective action program. Because of the nearly limitless possibilities for designing and implementing ground-water corrective actions, staff reviewers shall focus on the technical feasibility from an engineering perspective and evaluate whether the proposed design is likely to result in timely compliance with established concentration limits and whether the monitoring program is adequate to verify the effectiveness of the design. A ground-water corrective action program or a compliance monitoring program will be acceptable if it meets the following criteria:

(1) The selection of a restoration strategy conforms to the decision tree in figure 4-1 which was developed by the DOE (1993) and has been found acceptable by the NRC.

NRC has found the strategies to be acceptable for achieving compliance with ground-water protection standards:

(a) No remediation—This is an acceptable strategy at sites where ground-water contamination related to uranium processing activities is not present, or where contamination does not exceed either background levels, maximum concentration limits, alternate concentration limits, or supplemental standards, depending on the applicable regulatory requirements.

(b) Natural Flushing—Natural flushing is acceptable in accordance with 40 CFR 192.12(c)(2) and may be used in lieu of active remediation if the three following conditions are met: (i) either background concentrations, maximum concentration limits, or alternate concentration limits can be achieved within 100 yr; (ii) enforceable institutional controls will protect health and environment and satisfy beneficial uses of ground water during the natural flushing period; and (iii) the ground water is not now, nor is it projected to be, used as a source of public drinking water.

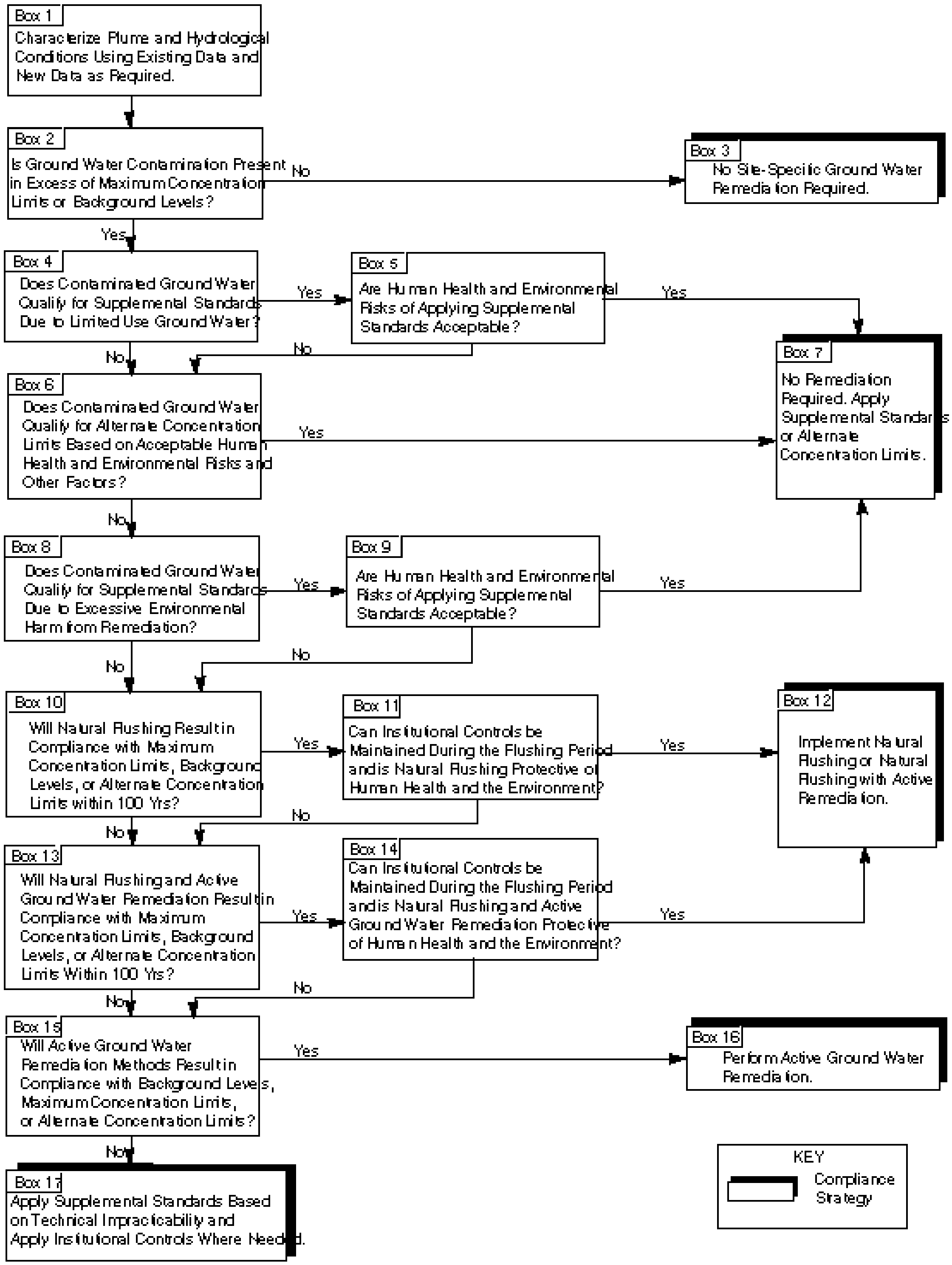

Figure 4-1 Ground-water compliance strategy selection.

Evaluation of natural flushing relies extensively on hydrogeologic data collected during the site characterization. The effectiveness of natural flushing in achieving cleanup standards is demonstrated using flow and transport models. The DOE identifies the model used to simulate the natural flushing process. Model development is described in terms of how model dimensions, grid spacing, and input parameters relate to the site conceptual model. Model inputs are summarized in tabular form, and an appendix containing model input and output files is included and referenced. Ideally, modeling results are presented as a series of contour plots that illustrate changes in the extent of contamination over time for each hazardous constituent. When practical, the DOE overlays contour plots on a site map—or provides points of reference—to show proximity of contaminants to local features. If the DOE demonstrates the efficacy of natural flushing by including the dilution effect of ground-water discharge to a surface water body, the reviewer shall ensure that assumptions regarding average flows are conservative. For example, stream dilution is estimated for an extended period of low discharge.

(c) Active remediation—Active remediation methods are employed at contaminated sites where contamination exceeds either background levels, maximum concentration limits, alternate concentration limits, or supplemental standards and natural flushing is not an acceptable alternative.

(e) A combination of active remediation and natural flushing—This option is appropriate for sites where contamination is of a limited aerial extent. Active remediation is employed at certain sections within the site while allowing the remainder of the site to flush naturally. This option is also appropriate for a scenario in which active remediation is used initially to reduce contamination to the point where natural flushing can then be used to meet restoration standards within 100 yr.

(2) The remedial action design and implementation is adequate.

When active remediation is necessary, a timetable for ground-water cleanup is established. This timetable can be based on model predictions of a design's likely restoration performance. When models are used to predict performance, a sensitivity analysis is performed to evaluate a variety of scenarios and their effect on the expected system performance. All modeling input parameters are based on site characterization data or on technically justified assumptions.

There are as many potential active remediation designs as there are contaminated sites. As such, it is beyond the scope of this standard review plan, and would be unnecessarily restrictive, to attempt to provide specific acceptance criteria for every possible active remediation scenario. In general, however, if active remediation methods are to be employed, a discussion of the type of active remediation is provided along with engineering specifications and an analysis of effectiveness.

Engineering specifications include design details such as pumping/injection rates, treatment methods, equipment and maintenance requirements, plans and schedules for construction, and maps showing locations of equipment.

An analysis is conducted to determine the expected effectiveness of the remediation system. Analyses are conducted to demonstrate that:

(a) The chosen active remediation technology is appropriate for the hydrogeologic and geochemical conditions at the site.

(b) Design pumping rates are sustainable and sufficient to control the migration of contaminants away from the site.

(c) The effects of natural aquifer heterogeneity are properly and conservatively accounted for in the remediation strategy.

(3) Adequate waste management practices are defined.

The disposition of effluent generated during active remediation is addressed in the corrective action plan. When retention systems such as evaporation ponds are used, design considerations from erosion protection and stability along with construction plans reviewed by a qualified engineer are included. Ideally the ponds should have leak detection systems capable of reliably detecting a leak from the pond into the ground water and should be located where they will not impede the timely surface reclamation of the tailings impoundment.

If water is to be treated and reinjected, either into the upper aquifer or into a deep-disposal well, the injection program is approved by the appropriate State or Federal authority. If effluent is to be discharged to a surface-water body, DOE obtains a National Pollutant Discharge Elimination System permit for discharge to surface water.

(4) Appropriate site access control is provided by the DOE.

Site access control should be provided by the DOE until site closure to protect human health and the environment from potential harm. Site access control is accomplished by limiting access to the site with a fence and by conducting periodic inspections of the site.

(5) Effective corrective action and compliance monitoring programs are provided.

The DOE's monitoring programs are adequate to evaluate the effectiveness of ground-water restoration and control activities, and to monitor compliance with ground-water cleanup standards. The description of the monitoring program includes or references the following information:

(a) Quality assurance procedures used for collecting, handling, and analyzing ground-water samples;

(b) The number of monitor wells and their locations;

(c) A list of constituents that are sampled and the monitoring frequency for each monitored constituent;

(d) Action levels that trigger implementation of enhanced monitoring or revisions to cleanup activities (i.e., timeliness and effectiveness of the corrective action).

Corrective action monitoring

The same wells used to determine the nature and extent of contamination may be used to monitor the progress of ground-water corrective action activities. An appropriate well configuration should be designed once the plume has been delineated and the rate and direction of ground-water flow has been established. The monitoring well configuration must be able to adequately evaluate performance of the remedial action and monitor compliance.

DOE chooses a monitoring interval that is appropriate for monitoring corrective action progress. Not all hazardous constituents need to be monitored at each interval. It is generally acceptable for DOE to choose a list of more easily measured constituents that serve as good indicators of performance. These indicators include conservative constituents that are less likely to be attenuated such as chloride, total dissolved solids, and alkalinity. However, if a hazardous constituent is causing a demonstrated risk to human health or the environment, that constituent must be monitored during the corrective action.

Termination of corrective action

The corrective action program may be terminated after the corrective action monitoring demonstrates that all hazardous constituents are at or below the licensed limits. An observation period, after active corrective action measures cease, is necessary to assure that hazardous constituents will remain at or below compliance limits and not begin to rise before the corrective action program is terminated. The length of this observation period is determined on a site-specific basis, with a minimum period of 1 year.

Compliance monitoring

After a corrective action program has been terminated, compliance monitoring at the point of compliance will resume as defined in the long term surveillance plan.

(6) Design of Surface Impoundments

The reviewer shall determine that any lined impoundment built as part of the corrective action program to contain wastes is acceptably designed, constructed, and installed. The design, installation, and operation of these surface impoundments must meet relevant guidance provided in Regulatory Guide 3.11, Section 1. Materials used to construct the liner shall be reviewed to determine that they have acceptable chemical properties and sufficient strength for the design application. The reviewer shall determine that the liner will not be overtopped. The reviewer shall determine that a proper quality control program is in place.

If the waste water retention impoundments are located below grade, the reviewer shall determine that the surface impoundments have an acceptable liner to ensure protection of ground water. The location of a surface impoundment below grade will eliminate the likelihood of embankment failure that could result in any release of waste water. The reviewer shall determine that the design of associated dikes is such that they will not experience massive failure.

The design of a clay or synthetic liner and its component parts should be presented in the application or related amendment applications for a uranium recovery operation. At a minimum, design details, drawings, and pertinent analyses should be provided. Expected construction methods, testing criteria, and quality assurance programs should be presented. Planned modes of operation, inspection, and maintenance should be discussed in the application. Deviation from these plans should be submitted to the staff for approval before implementation.

The liner for a surface impoundment used to manage uranium and thorium byproduct material must be designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the subsurface soil, ground water, or surface water at any time during the active life of the surface impoundment. The liner may be constructed of materials that allow wastes to migrate into the liner provided that the impoundment decommissioning includes removal or decontamination of all waste residues, contaminated containment system components, contaminated subsoils, and structures and equipment contaminated with waste and leachate.

The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure caused by pressure gradients, physical contact with the waste or leachate, climatic conditions, and the stresses of installation and daily operation. The subgrade must be sufficient to prevent failure of the liner caused by settlement, compression, or uplift. Liners must be installed to cover all surrounding earth that is likely to be in contact with the wastes or leachate.

Tests should show conclusively that the liner will not deteriorate when subjected to the waste products and expected atmospheric and temperature conditions at the site. Applicant test data and all available manufacturers' test data should be submitted with the application. For clay liners, tests, at a minimum, should consist of falling head permeameter tests performed on columns of liner material obtained during and after liner installation. The expected reaction of the impoundment liner to any combination of solutions or atmospheric conditions should be known before the liner is exposed to them. Field seams of synthetic liners should be tested along the entire length of the seam. Representative sampling may be used for factory seams. The testing should use state-of-the-art test methods recommended by the liner manufacturer. Compatibility tests that document the compatibility of the field seam material with the waste products and expected weather conditions should be submitted for staff review and approval. If it is necessary to repair the liner, representatives of the liner manufacturer should be called on to supervise the repairs.

Proper preparation of the subgrade and slopes of an impoundment is very important to the success of the surface impoundment. The strength of the liner is heavily dependent on the stability of the slopes of the subgrade. The subgrade should be treated with a soil sterilant. The subgrade surface for a synthetic liner should be graded to a surface tolerance of less than 2.54 cm (1 in) across a 30.3-cm (1-ft) straightedge. NRC Regulatory Guide 3.11, Section 2 (NRC, 1977) outlines acceptable methods for slope stability and settlement analyses, and should be used for design. If a surface impoundment with a synthetic liner is located in an area in which the water table could rise above the bottom of the liner, underdrains may be required. The impoundment will be inspected in accordance with Regulatory Guide 3.11.1 (NRC, 1980).

To prevent damage to liners, some form of protection should be provided, such as (a) soil covers; (b) venting systems; (c) diversion ditches; (d) side slope protection; and (e) game-proof fences. A program for maintenance of the liner features should be developed, and repair techniques should be planned in advance.

The surface impoundment must have sufficient capacity and must be designed, constructed, maintained, and operated to prevent overtopping resulting from (a) normal or abnormal operations, overfilling, wind and wave actions, rainfall, or run-on; (b) malfunctions of level controllers, alarms, and other equipment; and (c) human error. If dikes are used to form the surface impoundment, they must be designed, constructed and maintained with sufficient structural integrity to prevent their massive failure. In ensuring structural integrity, the applicant must not assume that the liner system will function without leakage during the active life of the impoundment.

Controls should be established over access to the impoundment, including access during routine maintenance. A procedure should be provided that ensures that unnecessary traffic is not directed to the impoundment area.

In addition, the reviewer shall evaluate the proposed surface impoundment to determine if it meets the definition of a dam as given in Regulatory Guide 3.11 (NRC, 1977). If this is the case, the surface impoundment should be included in the NRC dam safety program, and be subject to Section 215, National Dam Safety Program of the Water Resources Development Act of 1996. If the reviewer finds that the impoundment conforms to the definition of a dam, an evaluation of the dam ranking (low or high hazard) shall be made. If the dam is considered a high hazard, an emergency action plan is needed consistent with Federal Emergency Management Agency requirements. For low-hazard dams, no EAP is required. For either ranking of a dam, the reviewer shall also determine that the licensee has an acceptable inspection program in place to ensure that the dikes are routinely checked, and that performance is properly maintained.

A quality control program should be established for the following factors (a) clearing, grubbing, and stripping; (b) excavation and backfill; (c) rolling; (d) compaction and moisture control; (e) finishing; (f) subgrade sterilization; and (g) liner subdrainage and gas venting.

(7) Appropriate institutional control is provided for the site.

The primary purpose of institutional controls is to protect human health and the environment from potential harm while the site is being brought into compliance. Institutional controls are typically either government controls or property controls. Government controls include zoning restrictions, permit programs, well-drilling restrictions, and other restrictions that are traditionally established under the authority of governments. Property controls are legal devices, such as deed restrictions, easements, and restrictive covenants, that are based on state property law and are used to restrict the private use of a site. Care must be taken to assure that an institutional control is durable and enforceable. Successful implementation of institutional controls under long-term care, requires that difficulties such as keeping track of property ownership, enforcement of the controls, and variations in State property laws, are resolved during the review period. For the use of institutional controls on third party sites, staff should consult with NRC Office of General Council.

4.4 Evaluation Findings

If the staff review, results in the acceptance of the ground-water corrective action plan and compliance monitoring plans, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the ground-water corrective action and compliance monitoring plans at the _________________ uranium milling facility. The ground-water corrective action program should achieve the goal of returning hazardous constituent concentration levels in ground water to the concentration limits set as standards. The monitoring program will provide reasonable assurance that at the end of corrective actions the ground-water protection standard will not be exceeded.

The DOE has established a ground-water compliance strategy, that is acceptable for the site, which consists either of no remediation or active remediation, when contaminants are present at concentrations above background levels, maximum concentration limits, alternate concentration limits, or supplemental standards. When active remediation is necessary, the remedial action design and implementation are acceptable. The DOE has acceptably presented pumping/injection rates, treatment methods, equipment and maintenance requirements, and plans and schedules for construction, and has produced maps showing locations of remediation equipment. An analysis has been conducted that demonstrates: (1) the chosen active remediation system technology is appropriate for the site conditions; (2) design pumping rates are sustainable and will control migration of contaminants away from the site; and (3) the natural heterogeneity of the system has been acceptably accounted for in a conservative remediation strategy. The DOE has identified acceptable waste management practices. Institutional controls are appropriate for the site, including: (1) controlling access to the site; (2) conducting periodic inspections; and (3) periodically monitoring restoration performance. The monitoring program includes: (1) a description of quality assurance procedures; (2) the number of monitoring wells and their locations; (3) a list of constituents that will be sampled, along with the sampling frequency for each monitored constituent; and (4) action levels for triggering enhanced monitoring or revisions to cleanup activities. The DOE has described an acceptable scheme for restoration and compliance monitoring. The DOE will sample ground water at the point of compliance for all hazardous constituents of concern.

On the basis of the information provided in the application and the detailed review conducted of the ground-water corrective action and compliance monitoring plans for the _______________ uranium milling facility, the staff has concluded that the plans are acceptable and are in compliance with 40 CFR Part 192. If surface impoundments are to be used at the facility to manage byproduct material, their design has been found to be acceptable. If the surface impoundment meets the definition of a dam, it will be inspected and evaluated as part of the NRC's dam safety program.

4.5 References

DOE, 1993, "Technical Approach to Groundwater Restoration", DOE/AL62350-20F, November.

Environmental Protection Agency, 40 CFR Part 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings.

5.0 LONG-TERM SURVEILLANCE PLAN

5.1 Areas of Review

The staff shall review the following information in the long-term surveillance plan:

(5) (1) Description of the land ownership arrangements and the disposal area;

(6) (2) The location of background, points of compliance and if applicable points of exposure as to surface placement and aquifer completions

(3) Stipulations regarding inspection frequency, the frequency of reporting to the Commission, ground-water monitoring requirements, record keeping requirements, and quality assurance procedures;

(4)Criteria for initiating maintenance or emergency procedures. In 40 CFR 192.04 it is stated that "*if the groundwater concentration limits established for disposal sites under the provisions of § 192.02(c) are found or projected to be exceeded a corrective action program shall be placed into operation as soon as is practicable, and in no event later than eighteen (18) months after a finding of exceedance*".

5.2 Review Procedures

The reviewer shall examine ground-water standards to verify that they have been defined consistent with the acceptance criteria in this standard review plan. The staff will reference previously submitted descriptions of the geology, hydrology, geochemistry, and the ground-water corrective action strategy.

5.3 Acceptance Criteria

The long term surveillance plan will be acceptable with respect to water resources protection if it meets the following criteria:

(1) Background, points of compliance, and, if applicable, points of exposure have been located as described in the existing license. Wells should be correctly located as to surface locations and aquifer completions. Well locations should be surveyed in and should be located on site scale maps.

(2) If there has been no leakage from the impoundment into the ground water, appropriate ground-water parameters should be monitored and detection concentrations established that will provide early warning of leakage. Appropriate parameters should be indicative of the tailings material and not significantly affected by retardation reactions. For acid tailings appropriate detection parameters might include total dissolved solids, chloride or sulfate.

(3) The sampling frequency is sufficient to protect the public and environment at the point of exposure and sufficient to ensure that the ground-water downgradient of the point of compliance will not be degraded to any great extent before contamination is detected. This will require a knowledge of potential contaminant plume velocities. It is anticipated that the calculation of potential contaminant plume velocities will be based on advective calculations (ASTM Standards D5447, D5490, D5609, D5610, D5611, D5718, E978 and Anderson, 1992). However, more complex calculations that

include such processes as dispersion and retardation should be performed if site conditions warrant them. For sites with alternate concentrations limits, the sampling frequency should be sufficient to detect a potential contaminant plume, well before ground water at the point of exposure is degraded.

(4) It is anticipated for most sites that routine monitoring of once every three years will be acceptable unless site-specific conditions warrant an increased or decreased frequency of monitoring. If more frequent monitoring is required; the reviewer shall also need to identify the increase in the long-term care payment that must be made to support the more frequent monitoring. This increase will need to be included in the existing surety as well as the long-term care payment made at the time of license termination.

(5) Water quality sampling and analysis procedures use appropriate American Society of Testing and Materials or equivalent standards. Wells should be constructed to prevent surface-water contamination and capped and secured to prevent tampering by the populace (ASTM standard D5787).

(6) Any potential needs for future well maintenance or replacement are identified. If periodic well replacement is projected, an increase in the long-term care payment must be included (ASTM standard D5978).

(7) Actions that the long-term custodian would take should ground-water protection standards be exceeded are described.

5.4 Evaluation Findings

If the staff review results in acceptance of the long-term surveillance plan, the staff may conclude that DOE will conduct a Long Term Surveillance Plan that will confirm that constituents of concern will remain below the relevant standards in 40 CFR Part 192.

5.5 References

Anderson, M.P., and Woessner, W.W., 1992, *Applied Groundwater Modeling: Simulation of Flow and Transport. Academic* Academic Press, NY.

American Society for Testing and Materials (ASTM) Standards

D5447 Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem

D5490 Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information

D5609 Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling

D5610 Standard Guide for Defining Initial Conditions in Ground-Water Flow Modeling

D5611 Standard Guide for Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application

D5718 Standard Guide for Documenting Ground-Water Flow Model Application.

D5787 Standard Practice for Monitoring Well Protection.

D5978 Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells.

E978 Standard Practice for Evaluating Mathematical Models for the Environmental Fate of Chemicals.

Environmental Protection Agency, 40 CFR Part 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings.

APPENDIX A

GUIDANCE TO THE NRC STAFF
ON THE USE
OF STANDARD STATISTICAL HYPOTHESIS TESTING
AS APPLIED TO
GROUND-WATER QUALITY

APPENDIX A
GUIDANCE TO THE NRC STAFF
ON THE USE
OF STANDARD STATISTICAL HYPOTHESIS TESTING

Hypothesis Testing

Statistical hypothesis testing methods used for: (1) establishing background water quality; (2) establishing groundwater protection standards for compliance monitoring; (3) determining the extent of groundwater contamination; and (4) establishing the groundwater cleanup goals, are described in this appendix.

The following discussion on the use of standard statistical hypothesis testing is adapted from Environmental Protection Agency (EPA) guidance 1989a, b; 1993) and statistics texts (Haan, 1977; Gibbons, 1994; Abramson et al. 1988). The information presented here is referenced in other chapters of this SRP. Statistical hypothesis testing methods are used for: (1) establishing background water quality; (2) establishing groundwater protection standards for compliance monitoring; (3) determining the extent of groundwater contamination; and (4) establishing cleanup standards.

A statistical test of a hypothesis is a rule used for deciding whether a statement (i.e., null hypothesis) should be rejected in favor of an alternative statement (i.e., alternative hypothesis). The null hypothesis can be expressed as: "There is no difference between background and onsite water quality." The alternative hypothesis can be expressed as: "Onsite contaminant concentrations are above background." Because the concern lies only with concentrations of contaminants that are above background, this expression of the alternative hypothesis implies a one-tailed test of significance. Presumably, concentrations of any constituent in concentrations below background water quality pose no excess risk.

Two types of error are possible in hypothesis testing: the null hypothesis may be rejected when it is true (Type I error or false positive) or it may be accepted when it is false (Type II error or false negative). An example of Type I error in the context of this discussion would be to conclude that ground-water has been contaminated from mill tailings when, in fact, it has not. Thus, Type I error could result in unnecessary remediation. Conversely, Type II error could result in contaminated water being left untreated. In customary notations, a (alpha) denotes the probability of the hypothesis test leading to a Type I error, and ß (beta) denotes the probability of Type II error. Most statistical comparisons refer to the value 100a (in percent) as the level of significance. For example, if a = 0.01, there is a 1 percent chance of concluding that concentrations of contaminants are higher than background when they actually are not.

Before any groundwater monitoring criteria are determined, the implications of each type of error are considered. Clearly, if a Type I error is made, the error tends to favor protection of human health and the environment, but will result in unnecessary expenditure of capital. Thus, a higher value of a is more conservative when considering risk to human health and the environment; however, values that are too high could result in unrealistic restoration goals with little or no reduction in risk.

In testing hypotheses, the value for a is usually specified *a priori*. The value of ß, however, is not known unless the true parameter values being tested (e.g., the true background contaminant levels) are already known; this, of course, is rarely the case, as the parameter values are only estimated on the basis of a limited number of samples. In general, as the value of a decreases, the value of ß increases. The value of ß can also be reduced by ensuring that an adequate number of samples are obtained. Because an accurate assessment of background water quality is crucial to all subsequent monitoring efforts, the number of background samples collected should be sufficient to accept or reject the null hypothesis with a specified a.

Generally, the likelihood of Type II error can be sufficiently limited with a sample size that includes a minimum of six randomly distributed monitor well locations to capture spatial variations, and four sample periods to capture temporal variations. The Nuclear Regulatory Commission finds it acceptable to space sampling at least 2 weeks apart to capture temporal variations. Licensees are expected to take samples at greater intervals if seasonal variations are expected to be significant. The term “sample” is used to refer to the set of concentration measurements for each sampled constituent.

Thus, a single sample will contain at least 24 concentration measurements for each water quality parameter (constituent) of concern.

Ideally, background water quality is determined at a uranium mill site before the commencement of any milling operations. Background samples are collected both onsite and offsite. In the event that a mill site may have conducted operations before the determination of background water quality, then background may have to be determined using only offsite, upgradient samples. Once the background sample has been collected, some statistical analysis is required. The statistical analysis process can be divided into five major steps, and these steps are common to any data that are being analyzed. These steps will be referred to extensively in later sections. They include the following:

(1) Checking for the validity of statistical assumptions
(2) Handling nondetects
(3) Analysis of variance (ANOVA) test
(4 Analysis for statistical intervals
(5) Strategies for multiple comparisons

From the regulatory viewpoint, EPA recommends (Environmental Protection Agency, 1993) that a specific statistical analysis should be performed to meet the groundwater protection standards. The following table, Table B.1. summarizes the use of statistical methods.

Table B.1. Summary of Statistical Methods

Compound	Type of Comparison	Recommended Method
Any compound in background	Background versus compliance well	ANOVA Tolerance limits Prediction intervals
	Intra-well	Control charts
ACL/MCL specific*	Fixed standard	Confidence intervals Tolerance limits
Synthetic	Many nondetects in data set	Cohen's adjustment Aitchison's adjustment

*ACL%Alternate Concentration Limits; MCL --Maximum Concentration Limits.

Checking for the Validity of Statistical Assumptions

The inherent assumption with all parametric statistical methods described in Table B.1 is that the data being analyzed are normally distributed or can be transformed into a normal distribution. This assumption should be verified by testing the normality of data. If the measured data are not normally distributed, the log of measured data should be tested for lognormal distribution. In environmental compliance, measured concentration data will be most likely to be lognormally distributed. If the background sample exhibits variability in constituent concentrations over several orders of magnitude and a high positive skew, then log-transformation of the sample data may be necessary to obtain a distribution that more closely approximates normal. If the background sample exhibits a bimodal distribution due to zones of distinct water quality, it may be necessary to split the sample to obtain two normally distributed samples—one for each zone of water quality. When a sample is split, it may be necessary to obtain additional measurements from new sample locations, to obtain the minimum of six measurements for each distinct water quality zone. If bimodal distributions are encountered because of temporal variations, it is acceptable to evaluate the measurements collected during each sample period separately; this would result in four background samples, each containing a minimum of six measurements for each constituent. Whenever a bimodal distribution is encountered, the reviewer shall verify that it is caused by changes in natural variations in water quality, and not caused by the presence of contamination.

Summary statistics are calculated for the background sample. The two most important statistics for hypothesis testing are the mean and standard deviation. For normal distributions, the mean represents the arithmetic mean; for log-normal distributions, the mean represents the geometric mean of the sample data. The various methods that can be used for testing the normality or lognormality of data are: Probability Plots, Coefficient of Skewness, Shapiro-Wilk test, Shapiro-Francia test, and Probability Plot Correlation Coefficient (Environmental Protection Agency, 1993). If the assumption of lognormality is valid, further statistical analyses should be performed. However, if the data are neither normal nor lognormal, a non-parametric technique should be used.

Handling Nondetects

If fewer than 15 percent of all samples are nondetect, replace each nondetect by half its detection or quantitation limit. Care should be taken in choosing between the method detection limit (MDL) and the physical quantitation limit (PQL) (Environmental Protection Agency, 1993). The nondetects are reported as “undetected” or “detected but not quantified” and with or without an estimated concentration. If an estimated concentration value is given, the value should be used for statistical analysis. Otherwise, nondetects should be substituted by one-half of PQL since PQL is a better representative of actual laboratory conditions than MDL. After this correction, the data can be analyzed by any parametric approach, (e.g., ANOVA or statistical interval).

If more than 15 percent but fewer than 50 percent of all samples are nondetects, either Cohen’s adjustment or Aitchison’s (Environmental Protection Agency, 1993) adjustment should be applied. If more than 50 percent but fewer than 90 percent of the samples are nondetects, nonparametric statistical intervals, for example, Poisson Prediction Limit (Environmental Protection Agency, 1993), should be used.

Analysis of Variance (ANOVA) Test

The ANOVA test is used to compare concentration data from several compliance wells with concentration data with background wells. This method is used to test for the statistically significant evidence of higher mean concentration in compliance wells than the background concentration as provided by background wells. ANOVA is best used for comparisons between wells that are hydraulically upgradient of a site and those that are downgradient from the site. The parametric ANOVA technique makes two key assumptions: (1) that the data residual are normally distributed and (2) that the group variances are approximately equal. If any of these assumptions are not valid, it is recommended that a nonparametric approach, such as the Kruskal-Wallis test or the Wilcoxon Rank-Sum test (also known as the Mann-Whitney U test) (Environmental Protection Agency, 1993), is used in analyzing the data. The Kruskal-Wallis test is used when three or more well groups are compared; however, for comparing one compliance well with one background well, the Wilcoxon Rank-Sum test should be used. A non-parametric ANOVA based on ranks, followed by multiple comparison procedures can be used to identify statistically significant evidence of contamination. The method includes estimation and testing of the contrasts between each compliance well median and the background median levels for each constituent.

Analysis for Statistical Intervals

There are three types of statistical intervals that are most commonly constructed from the data: confidence intervals, tolerance intervals, and prediction intervals. The interpretation and use of each of these intervals is quite distinct. A confidence interval is a random interval that is designed to contain the specified population parameter with a designated level of confidence or probability, denoted as 1!a. A confidence interval should be used only in two situations for groundwater data analysis:
(1) when directly specified by permit or (2) in compliance monitoring, when downgradient samples are being compared with a fixed groundwater protection standard, (e.g., Part 40 or ACLs). In other cases, it is usually desirable to use either tolerance or prediction intervals.

A tolerance interval, also random interval, is designed to contain a designated proportion of population with a certain confidence level. Two coefficients are associated with any tolerance interval: coverage and tolerance coefficients. Coverage is the proportion of the population that the interval is supposed to contain and the tolerance coefficient is the degree of confidence with which the interval reaches the specified coverage. A tolerance interval with coverage of 99 percent and a tolerance coefficient of 99 percent are constructed to contain, on average, 99 percent of the distribution with a probability of 99 percent. Since a tolerance interval is designed to cover all but a small percentage of the population's measurements, observations should rarely exceed the upper tolerance limit when testing small sample size. The tolerance intervals can be used in detection monitoring when comparing compliance data with background values. They can be used in compliance monitoring when comparing compliance data with certain fixed standards, (e.g., Part 40 or ACLs).

A one-sided test of significance is used to determine the upper limit of the range of background concentrations. This is also known as the tolerance limit method. This limit is given by

$$U = \bar{x} + t_{?,?} s_x \qquad (4.1)$$

where $\bar{x}$ is the mean value determined for the background sample; s_x is the standard deviation of the background sample; $t_{?,?}$ is the *t*-statistic for ? = (1 − a); and ? = (n − 1) of degrees of freedom, where n is the number of background measurements for each constituent. Values for *t*-statistics are obtained from *t*-tables that can be found in most basic statistics textbooks. The value of *U* for each constituent is interpreted as the maximum concentration of that constituent that may be present in any single monitor well without concluding that the constituent concentration is above the range of reasonable background concentrations.

Equation (4.1) is used for determining whether constituent concentrations meet the background criterion in any single well. However, it is often the case that a licensee wishes to demonstrate compliance with the background criterion by using well field average concentrations for each constituent. That is, while a concentration in one or more wells may exceed background, the water quality of the aquifer, on average, meets the background criterion. NRC finds this approach to be acceptable; however, it necessitates a change to Eq. (4.1). Rather than the standard deviation of the single background sample (s_x), the standard deviation of the sample average (s_x) must be used. Normally, this would require that at least six background samples be collected, the mean of each sample be determined, and a calculation be made of the standard deviation for these background sample means. However, it is rarely the case that enough background samples are collected to calculate $s_{\bar{x}}$ directly. For these purposes, $s_{\bar{x}}$ can be approximated by the equation

$$s_{\bar{x}} = \frac{s_x}{\sqrt{n}} \qquad (4.2)$$

A prediction interval is a statistical interval calculated to include one or more future observations from the same population with a specified confidence. In groundwater monitoring, a prediction interval approach can be used in two ways: (1) to compare compliance well data with background well data and (2) to make intrawell comparisons for an uncontaminated well. If future observations are found to be in the prediction interval, then there is no contamination. However, if the measured concentration is above the prediction interval's upper limit, it is statistically significant evidence of contamination.

Another commonly used technique for intrawell comparison is control charts (Environmental Protection Agency, 1993). The control chart method is recommended for uncontaminated wells only. This is an effective technique to monitor contamination over time. The control charts should be constructed with data that are free from seasonal variability. It is important to note that the control charts should not be used for wells that show evidence of contamination or an increasing trend.

Strategies for Multiple Comparisons

When more than one statistical test is performed during any monitoring period, the problem of multiple comparisons needs to be addressed. These comparisons can arise from the fact that multiple compliance wells were tested against multiple background wells for several contaminants. Usually the same statistical test is performed in every comparison, each test having a fixed level of confidence $(1-\alpha)$, and a corresponding false positive rate, α.

The selection of an α value is not arbitrary: the consequences that would result from Type I error must be considered. In most cases, Type I error favors protection of human health and the environment, but results in unnecessary expenditure of capital for restoration. Thus, a higher value of α is more conservative when considering risk to human health and the environment; however, values that are too high could result in unrealistic cleanup standards, with little or no reduction in risk. EPA recommends an α-value of 0.05 (Environmental Protection Agency, 1989a). The number of contaminants present at a site should also be considered when selecting a value for α. For example, the EPA-recommended α-value of 0.05 translates to a 1-in-20 chance of Type I error. However, if 20 constituents are being evaluated for cleanup standards, and each has a 1-in-20 chance of Type I error, the result is a 64 percent chance that at least one Type I error will occur. In such cases, using an α-value of 0.05 is likely to result in unnecessary restoration. However, α-values lower than 0.01 should not be used at sites where public water supplies or sensitive environmental areas may be threatened by contamination.

Once a background sample has been properly collected and analyzed for each constituent of concern, it is then possible to conduct hypothesis testing for establishing cleanup standards and groundwater protection standards, and for determining the extent of any existing contamination. The review should confirm that the statistical method used complies with the following, as appropriate:

(1) The statistical method used to evaluate groundwater monitoring data is appropriate for the distribution of chemical parameters or hazardous constituents. If the distribution of the chemical parameters or hazardous constituents is shown by the owner or operator to be inappropriate for a normal theory test, then the data are transformed or a distribution-free theory test is used. If the distributions for the constituents differ, more than one statistical method is needed.

(2) If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a groundwater protection standard, the test is done at a Type I error level no less than 0.01 for each testing period. If a multiple comparisons procedure is used, the Type I error rate for each testing period is no less than 0.05; however, the Type I error of no less than 0.01 for individual well comparisons is maintained. This does not apply to tolerance intervals, prediction intervals, or control charts.

(3) If a control chart approach is used to evaluate groundwater monitoring data, the specific type of control chart and its associated parameter values are proposed by the licensee.

(4) If a tolerance interval or a prediction interval is used to evaluate groundwater monitoring data, the levels of confidence and, for tolerance intervals, the percentage of the population that the interval must contain, are proposed by the licensee. These parameters are determined after considering the number of samples in the background database, the data distribution, and the range of the concentration values for each constituent of concern.

(5) The statistical method accounts for data below the limit of detection with one or more statistical procedures that are protective of human health and the environment. The limit of detection that is used in the statistical method is the lowest concentration level that can be reliably achieved, within specified limits of precision and accuracy, during routine laboratory operating conditions that are available to the facility.

(6) If necessary, the statistical method includes procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data.

References

Abramson, L.R., et al., 1988, “Statistical Methods for Nuclear Material Management,” Nuclear Regulatory Commission, NUREG/CR-4604, 1988.

Gibbons, R.D., 1994, *Statistical Methods for Groundwater Monitoring.* New York, NY: John Wiley & Sons, Inc., 1994.

Haan, C.T., 1977, *Statistical Methods in Hydrology*, Ames, IA: Iowa State University Press, 1977.

Environmental Protection Agency, 1989a, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance*, EPA/530/SW-89/026, 1989.

Environmental Protection Agency, 1989b, *Risk Assessment Guidance for Superfund,” Vol. I, Human Health Evaluation Manual (Interim Final 9/29/89),* OSWER Directive 9285.7-01a, 1989.

Environmental Protection Agency, 1993, *Statistical Training Course for Groundwater Monitoring Data Analysis,* EPA/530-R-93-003, 1993.